Vegetation cover and wetland complex size as predictors of bird use of created wetlands in Ohio

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Abstract

To enhance the overall quality of wetland habitats, it is important to demonstrate which types of wetlands provide adequate habitat for which groups of wetland-dependent organisms. The objectives of this study are to examine the association between wetland bird species diversity and the a) type of emergent vegetation cover and b) size of the wetland complex within which a wetland was constructed. 18 constructed palustine emergent wetlands within the Till Plains Ecoregion of central Ohio were chosen for this study. Study sites were from 3 to 8 years old, and ranged in size from 2.8 to 4.1 ha. Study sites were classified into wetlands with peripheral emergent vegetation (10% emergent vegetation cover), low-end hemi-marshes (30%) and high-end hemi-marshes (60% emergent vegetation cover). Study sites were further divided into three categories based on the size of the wetland complex within which the study site was located (<2 ha, >2ha and <5 ha, and >5 ha). Waterfowl and shorebird migration, and spring point-count surveys of breeding birds were conducted in 2001 and 2002.

High vegetation cover wetlands (>60% vegetation cover) had the highest breeding bird and overall species richness. With the exception of pie-billed grebes, Canada geese and mallards, all breeding species attained highest densities in this wetland type. Densities of migrating waterfowl and shorebirds were highest in low-end hemi-marsh wetlands (30% vegetation cover). Species richness and densities of several species and groups of species, including migrating waterfowl, were associated with the size of the wetland complex within which the study site was created. Results of this study indicate that wetland birds differ in their habitat requirements, and that creation of different wetland types is necessary to maintain bird diversity. Creation of wetland complexes consisting of different wetland types should be favored over the creation of a single, large cell, all else being equal.

Introduction

Under£404 and£401 of the Federal Water Pollution Control Act and subsequent amendments (The Clean Water Act), the approval to fill, drain or otherwise degrade a wetland in the USA may be conditional on restoring, creating or enhancing wetlands to compensate for any unavoidable loss in wetland area and function. Replacement ("mitigation") wetlands are built with the intent to replace all of the functions of lost wetlands, including storm water detention, water purification, nutrient cycling, ground water recharge and wildlife habitat (US Department of the Army and US Environmental Protection Agency 1990). However, replacement of wildlife habitat is usually not one of the functions monitored or regulated (National Research Council 1995, 2001).

With historical wetland losses nearing 90% within the Midwestern states (Dahl 1990), we have to focus our attention on creating wetland habitats that can contribute substantively to the preservation of diverse wetland-dependent fauna. Different types of wetland designs may satisfy hydrological, soil and vegetation criteria for successful wetland replacement but, it is also important to demonstrate which types of wetlands provide adequate habitat for different groups of wetland-dependent organisms. Failure to do so may result in creation of habitats suitable for only a limited number of species.

Recent studies of replacement wetlands indicate that they tend to have longer, less variable hydroperiods than the impacted sites, and are therefore often dominated by open-water/aquatic bed habitat (Illinois - Gallinugh 1998; Pennsylvania - Campbell 1996, Cole and Brooks 2000; Indiana - Robb 2000; Ohio – Porej 2003; New England - Minkin and Ladd 2003; Tennessee - Morgan and Roberts 2003). In a study that compared natural to replacement wetlands in Ohio, Fenessy (1997) concluded that the average bank slopes of replacement wetlands are significantly steeper than in natural reference wetlands. Absence of a shallow littoral zone may limit the amount of vegetation cover and reduce the number of adequate foraging and nesting sites for certain groups of wetland-dependent bird species. For example,–of >150 species that use moist-soil impoundments in Missouri, only 23 regularly use water depths >25cm and, of these, all but 7 generally use water <25cm deep (Frederickson and Reid 1986; see also review by Weller 1999 and references therein).

Another important issue in wetland replacement is whether to encourage individual on-site wetland replacement or to encourage creation of larger wetland complexes. Several studies have demonstrated an association between the species richness and the amount of wetland habitat surrounding the study wetland (Gibbs et al. 1991, Brown and Dinsmore 1996, Fairbairn and

Dinsmore 2001). Wetland complexes may create habitat diversity that is attractive to different species of birds, provide suitable habitat for species requiring different wetland types to complete their life cycle (Delnicki and Rienecke 1986, Fredrikson and Reid 1986), and may harbor area-sensitive species (Vanrees-Siewart and Dinsmore 1996, Weller 1999, Ratti et al. 2001).

While a significant body of work exists for bird use of restored prairie potholes (Brown and Dinsmore 1996, Vanrees-Siewart and Dinsmore 1996, Fairbairn and Dinsmore 2001), relatively little is known about restored marshes in the Midwest outside that region (e.g., Hartman 1994). The objectives of this study are to examine the association between wetland bird species diversity, relative density estimates of individual species and within-wetland habitat characteristics (type of vegetation cover) and the size of the wetland complex within which a wetland was constructed.

The two main questions I will address are:

a) How does the amount of emergent vegetation cover affect overall species richness and densities of individual wetland-dependent bird species in palustrine emergent created/restored wetlands? I will compare bird use of replacement wetlands dominated by open water/aquatic bed habitats to wetlands that represent low and high-end hemi-marsh conditions (~30% and ~70% vegetation cover, respectively). I expect that neither wetland type would be suitable habitat for all species. I also expect that wetlands with high amounts of vegetation cover will provide suitable habitat for more species than wetlands dominated by open water habitat.

b) Is overall species richness and densities of individual species associated with the size of the wetland complex within which the study wetland is located? I expect that wetlands located within larger complexes will have higher diversity than isolated wetlands.

I will also report the results of my surveys of all wetlands constructed under £401 permits in Ohio from 1990-1999, and comment on the effect our current wetland replacement practices may have on maintaining avian diversity within our region.

Study sites

Study sites were 18 replacement wetlands constructed under£401 of the Clean Water Act as mitigation for unavoidable wetland losses. Based on pre-construction reports and presence of hydric soils, most of the sites (>85%) were a combination of wetland restoration and creation. All wetlands were a Type III (seasonal marsh) or Type IV (semipermanent marsh) wetlands (Stewart and Kantrud 1971). Wetlands were from 3 to 8 years old at the beginning of the study, and ranged in size from 2.8 to 4.1 ha. Studies of associations between bird use and wetland age have showed mixed results (Delphey 1991, Hemesath and Dinsmore 1993, Brown 1995, VanRees-Siewart amd Dinsmore 1996, Brown and Smith 1998, Hotaling et al 2002). Some data suggests that created wetlands begin approaching natural wetlands in bird diversity after about 4 years (Delphey 1991, Brown and Smith 1998). In some cases, possible effects of age were confounded by differences in vegetation cover between newer and older sites (e.g., VanRees-Siewert and Dinsmore 1996, Hotaling et. al 2002). To avoid possible confounding effects, sites that differ in the pattern of vegetation cover, but are of similar age were chosen for this study.

All study sites were located within the Till Plains Ecoregion of central Ohio. Landscape is dominated by intensive row-crop corn and soy-bean agriculture, with scattered small woodlots and few pastures.

Study sites were classified into three categories based on the vegetation cover pattern (Table 1.):

1) “Perimeter wetlands” (Type 1)- central expanse of open water and scattered stands of emergent wetland vegetation, less than 2m in average width, along the wetland perimeter,

2)“Low vegetation cover wetlands” (Type 2)- a central expanse of open water and a band of emergent vegetation wider than 2m on average, and

3) High vegetation cover wetlands (Type 3)- scattered pools of open water interspersed within emergent vegetation.

Table 1. Characteristics of replacement wetland study sites studied in 2001/02 in Till Plains Ecoregion of central Ohio

	Perimeter wetlands (Type 1)	Low vegetation cover wetlands (Type2)	High vegetation cover wetlands (Type 3)
N	6	6	6
AGE (years)	5.2 ± 0.7	5.5 ± 0.9	5.3 ± 0.7
SIZE (ha)	3.45 ± 0.18	3.37 ± 0.16	3.25 ±0.23
% Aquatic bed / open water	87.1 ± 1.8	64.5 ± 3.3	21.7 ± 2.7
% Emergent vegetation	9.0 ± 1.7	29.0 ± 3.1	63 ± 5.6
% Shrub vegetation	3.8 ± 1.7	6.5 ± 1.8	15.1 ± 3.1
Mean cover: water ratio	1 : 0.15	1 : 0.56	1 : 4.11
Mean edge : perimeter ratio	0.032 ± 0.007	0.038 ± 0.007	0.034 ± 0.006

Bird use of wetlands is dependent more on the vegetation structure and cover pattern than the actual plant species (Weller and Spatcher 1965). Weak stemmed emergent vegetation (Weller and Spatcher 1965, Kantrud et al. 1989) formed <10% of the total emergent vegetation cover, and I grouped robust- and weak-stemmed categories into a single category. All wetlands lacked wet meadow zones. Study sites were further divided into three categories based on the amount of additional wetland habitat in the complex within which the study site was located (COMPLEX 1 <2 ha, COMPLEX 2 >2ha and <5 ha, and COMPLEX 3 >5 ha). Two sites were therefore assigned to each one of nine groups, based on the combination of vegetation cover (3 types) and the size of the complex within which the site was located (3 categories).

Site boundaries and vegetation maps were recorded using Trimble® GeoXT global positioning system with real-time differential correction and Bushnell Yardage Pro“ 500 Laser Rangefinder in both years. In cases when real-time differential correction was not possible, post-processing of data was completed later. Using either of the two correction methods, Trimble GeoXT achieves sub-meter accuracy.

Total precipitation in central Ohio during the period between 1 March and 1 July was close to average in 2001 (-1.73cm), and +20.94cm above average in 2002 (Ohio Agricultural Research and Development Center, Columbus, Ohio).

Other wetlands constructed under £401 in Ohio

In addition to the eighteen study sites, in 2002-2003 I have visited all replacement wetlands that were created or restored under Ohio EPA£401 permits issued before Jan 1 2000. All wetlands were delineated using the methods described above. For these sites, vegetation cover was estimated using Bushnell Yardage Pro“ 500 Laser Rangefinder. Wetlands were classified according to the amount of vegetation cover into three cover types as described above.

Methods

For this study, all observed wetland-dependent and wetland-associated birds (after Crowley et al. 1996, and Brown and Smith 1998) were recorded (Table 2).

Waterfowl migration survey

Migrating waterfowl were counted four times from 15 March 15 to 15 April in both years. Waterfowl were counted and identified from a pre-determined survey point, followed by a walk around the wetland perimeter.

Breeding bird survey

Each site was surveyed three times during each year. Surveys were conducted from May to June (3 May – 26 June 2001, 1 May— 22 June 2002). The date and time of site visits was randomized within each survey period.

Point-count (Ralph et al.1993, 1995) and call-response (playback) methods (Gibbs and Melvin 1997, Ribic et al. 1999) were used to survey birds in each wetland. Surveys were conducted from sunrise to 1000 AM. Order of site visits was randomized within each study period. An array of five survey points was established at each site prior to the first survey, and locations of survey points were maintained in both years. Survey points were placed in the emergent vegetation zone or at the wetlands edge when emergent vegetation was absent. The area surveyed around each point was a full circle with a 50 m radius unless the survey point was located near the edge of the wetland.

All birds heard or seen within 7-minute counting period at each survey point were recorded. During the middle 3 min, a tape player was used to play back vocalizations of least bittern (*Ixobrychus exilis* Gmelin), Virginia rail (*Rallus limicola* Vieillot), sora (*Porzana carolina* Linnaeus), common moorhen (*Gallinula chloropus* Linnaeus), American bittern (*Botaurus lentiginosus* Rackett), and pied-billed grebe (*Podiceps nigricollis* Linneaus). Birds whose flight originated or terminated within plot boundary, and those that flushed as I approached the survey point were included in the count. For active species like swallows only the highest number observed at any point along the survey route was recorded.

Active nests, young, or proportions of records of at least one adult was used to determine the species breeding status. One adult (one indicated pair for Anatinae) must have been present during at least two visits to be counted as a breeding species (Brown and Dinsmore 1986, Inman et al. 2002). Species nesting in colonies (e.g., herons, swallows) were classified as “non-nesters” since the location of the colony was not known, and is assumed to be independent of the variables studied. All wetland-associated species were classified as “non-nesters” as well. Bird densities were calculated as the average number of individuals recorded per site visit for each year, except for mallards, wood ducks and Canada geese. For mallards and wood ducks I recorded the number of breeding or indicated pairs (Dzubin 1969), and for Canada geese I use the number of nests/site during each year in the analyses.

Individual counts were averaged across five study points for each study site for every bird species. These densities may not reflect true densities because some species are easier to detect than others and may behave differently during counts. However, calculated densities are relative measures of abundance and were used for comparisons between study sites.

Statistical analysis

Correlations between wetland size, age and vegetation cover were examined using Pearson’s correlation coefficient. Comparisons of mean age, size, and vegetation cover between wetlands grouped according to the vegetation cover were performed using one-way ANOVA. The same

Table 2. Bird species observed in 18 replacement wetlands in central Ohio in 2001-2002. Observed breeding status as follows (B) – breeding, (V) – visitor, non-breeder

		Breeding status	
Wetland-dependent	Alder flycatcher	V	*Empidonax alnorum* Brewster
	American bittern	V	*Botaurus lentiginosus* Rackett
	American coot	V/B [(a)]	*Fulica americana* Gmelin
	Belted kingfisher	V	*Ceryle alcyon* Linnaeus
	Blue-winged teal	V/B [(a)]	*Anas discors* Linnaeus
	Bl.-crowned night-heron	V	*Nycticorax nycticorax* Linnaeus
	Canada goose	B	*Branta Canadensis* Linnaeus
	Cattle egret	V	*Bubulcus ibis* Linnaeus
	Common snipe	V	*Gallinago gallinango* Linnaeus
	Common yellowthroat	B	*Geothlypis trichas* Linnaeus
	Great blue heron	V	*Ardea herodias* Linnaeus
	Great egret	V	*Ardea alba* Linnaeus
	Green heron	V	*Butorides virescens* Linnaeus
	Least bittern	V/B [(a)]	*Ixobrychus exilis* Linnaeus
	Mallard	B	*Anas platyrhynchos* Linnaeus
	Marsh wren	B	*Cistothorus palustris* Wilson
	N. rough-winged swallow	V	*Stelgidopteryx serripennis*
	Pie-billed grebe	B	*Podilymbus podiceps* Linnaeus
	Red-winged blackbird	B	*Agelaius phoeniceus phoeniceus* Linnaeus
	Sora	B	*Porzana Carolina* Linnaeus
	Spotted sandpiper	B	*Actitis macularia* Linnaeus
	Swamp sparrow	B	*Melospiza georgiana* Latham
	Tree swallow	V	*Tachycineta bicolor* Vieillot
	Virginia rail	B	*Rallus limicola* Vieillot
	Willow flycatcher	B	*Empidonax traillii* Audubon
	Wood duck	B	*Aix sponsa* Linnaeus
Wetland-associated			
	Barn swallow	V	*Hirundo rustica*
	Common grackle	V	*Quiscalus quiscula*
	Eastern kingbird	V	*Tyrannus tyrannus* Linnaeus
	Eastern phoebe	V	*Sayornis phoebe* Latham
	Gray catbird	V	*Dumetella carolinensis*
	Kildeer	V	*Charadrius vociferous* Linnaeus
	Yellow warbler	V	*Dedroica petechia* Linnaeus
WATERFOWL MIGRANTS			
	American black duck		*Anas rubripes* Brewster
	American widgeon		*Anas Americana* Gmelin
	Bufflehead		*Bucephala albeola* Linnaeus
	Common goldeneye		*Bucephala clangula*
	Gadwall		*Anas streptera* Linnaeus
	Greater scaup		*Aythya marila* Linnaeus
	Green-winged teal		*Anas crecca* Linnaeus
	Hooded merganser		*Lophodytes cucullatus* Linnaeus
	Lesser scaup		*Aythya affinis* Eyton
	Northern pintail		*Anas acuta* Linnaeus
	Northern shoveler		*Anas clypeata* Linnaeus
	Red-breasted merganser		*Mergus merganser* Linnaeus
	Redhead		*Aythya americana* Eyton
	Ring-necked duck		*Aythya collaris* Donovan
	Ruddy duck		*Oxyura jamaicensis* Gmelin
MIGRANT SHOREBIRDS			
	Greater yellowlegs		*Tringa melanoleuca* Gmelin
	Least sandpiper		*Calidris minutilla* Vieillot
	Lesser yellowlegs		*Tringa flavipes* Gmelin
	Semipalmated plover		*Charadrius semipalmatus* Bonaparte
	Semipalmated sandpiper		*Calidris pussila* Linnaeus
	Solitary sandpiper		*Tringa solitaria* Willson

[(a)] Breeding documented only at two sites procedure was employed to test for differences between means when wetlands were grouped according to the size of the wetland complex.

Individual species counts were analyzed using univariate GLM repeated-measures procedure. Analysis of variance was performed with year as within-subject factor, and wetland vegetation cover type (3 levels) and wetland complex (3 levels) as main effects. Age and size of the wetland were entered in the analyses as covariates. Since each cell contained the same number of data points, type III sums of squares method was used to calculate the sums of squares for the between-subject model. Benjamini-Hochberg false discovery rate controlling procedure (Benjamini and Hochberg 1995) was used to control the family error rate in tests of main effects for individual species within groups (e.g., breeding bird species, non-breeding species). False discovery rate was set at q = 0.10. The procedure was as follows:

I ordered the *p* values corresponding to null hypotheses tested as $P_{(1)} \leq P_{(2)} \leq \ldots \leq P_{(m)}$, and denoted by $H_{(i)}$ the null hypothesis corresponding to $P_{(i)}$. I let *k* be the largest *i* for which

$P_{(i)} \leq (i/m) * q$;

then rejected all $H_{(i)} = 1,2,\ldots, k$.

Post-hoc pairwise comparisons among the levels of significant main effects within species and groups of species were performed using Bonferroni confidence interval adjustment.

Results

Characteristics of study sites

There was no correlation between age of the wetland study sites and wetland size (r = 14, p = 0.58) or percent of vegetation cover (r = 0.21, p = 0.40). There was no correlation between wetland size and the percent of vegetation cover (r = -0.10, p = 0.69).

There was no significant difference in mean age ($F_{(2,17)}$ = 0.61, p = 0.56, one-way ANOVA), mean size ($F_{(2,17)}$=0.28, p = 0.763), or edge:area ratio ($F_{(2,17)}$ = 1.31, p = 0.30) between perimeter wetlands, low vegetation, and high vegetation cover study sites. There was significant heterogeneity in mean % emergent cover ($F_{(2,17)}$ = 147.96, p <0.01), and % open water/aquatic bed habitat ($F_{(2,17)}$ = 158.12, p <0.01) among different types of wetland sites (Table 2; post-hoc test with Bonferroni adjustment). Type 3 wetlands had significantly higher % shrub cover than the other two categories of study sites ($F_{(2,17)}$ = 6.54, p <0.01, one-way ANOVA; post-hoc test with Bonferroni adjustment).

There was no significant difference in mean age ($F_{(2,17)}$ = 1.38, p = 0.28, one-way ANOVA), mean size ($F_{(2,17)}$ = 0.27, p = 0.76, one-way ANOVA), mean amount of vegetation cover ($F_{(2,17)}$ = 0.08, p = 0.923, one-way ANOVA), mean cover:water ratio ($F_{(2,17)}$ = 0.28, p = 0.75, one-way ANOVA), mean edge:area ratio ($F_{(2,17)}$ = 2.13, p = 0.16, one-way ANOVA) between wetlands grouped based on the size of the complex.

Other wetlands constructed under£401 in Ohio

The size and vegetation cover type for a total of 104 replacement emergent marshes were recorded. Distribution of the replacement wetlands among different vegetation cover types is presented in Porej 2003b.

Wetland age and size

Wetland age (range 3-8 years) and size (range 2.8-4.1ha) were not a significant factor in predicting bird use of replacement wetlands in this study (p>0.05 in all tests).

Numbers and densities of individual species and groups of birds

A total of 54 wetland-dependent and wetland-associated bird species during the two years of the study.

Breeding birds

Breeding was documented for 15 species, and there were sufficient data to test the association between observed densities and study variables for 11 species (Table 3). Swamp sparrows were recorded at only five sites (breeding at four), none of which were perimeter wetlands. Least bittern were observed at two sites (breeding in both), both high-vegetation marshes within large complexes. American coots and blue-winged teals were recorded at thirteen and seventeen sites respectively, but breeding was documented at only two sites in one year. These two species were therefore grouped with the“non-breeders”. Seven breeding species had highest observed densities in high vegetation cover wetlands, two species in low vegetation cover wetlands (mallard, Canada goose), and one species in perimeter wetlands (pie-billed grebe). Density of four species was positively associated with the size of the wetland complex (marsh wren, common yellowthroat, willow flycatcher, mallard).

Breeding bird species richness was highest in high vegetation cover wetlands, and lowest in perimeter wetlands (Table 4).

Non-breeding birds

Twenty non-breeding bird species were recorded, and there was sufficient data to analyze habitat associations for 11 species (Table 3). Species richness in the “non-breeders” group was significantly higher in both high and low vegetation wetlands than in perimeter wetlands. Species richness was significantly higher in wetlands within larger wetland complexes (Complex 3) than in isolated wetlands or wetlands located within smaller complexes (Table 4).

All species (excluding migrant waterfowl and shorebirds)

Overall species richness was significantly higher in both high and low vegetation wetlands than in perimeter wetlands (Table 4). There was no evidence for the association between overall species richness and the size of the complex within the study site was located ($F_{(2.17)}$ = 2.78, p = 0.13).

Table 3. Comparisons between counts of individual bird species observed at replacement wetlands in Ohio 2001-2002. (the analysis of variance for TYPE and COMPLEX main effects, and significant differences between means for different levels of TYPE and COMPLEX. Differences in means for pairwise comparisons between levels are negative when the mean for the second level was higher than the mean for the first level)

Test of between-subject effects				Pairwise comparisons among the levels of main between-subject effects					
				TYPE			COMPLEX		
		$F_{(2.17)}$	P	Comp.	Mean diff.	P	Comp.	Mean diff.	P
Marsh wren	TYPE	15.59	<0.01	3-1	1.78	<0.01	3-1	1.27	0.01
	COMPLEX	8.45	0.014	3-2	1.21	0.011			
C. yellowthroat	TYPE	98.58	<0.01	3-1	2.29	<0.01	3-1	0.91	<0.01
	COMPLEX	16.14	<0.01	3-2	1.51	<0.01	3-2	0.82	<0.01
				2-1	0.78	<0.01			
Willow flycatcher	TYPE	31.18	<0.01	3-1	1.98	<0.01	3-1	1.36	<0.01
	COMPLEX	14.67	<0.01	3-2	1.32	<0.01	3-2	1.17	0.013
Red-winged blackbird	TYPE	13.52	0.011	3-1	10.17	<0.01			
				2-1	5.51	0.041			
Sora	TYPE	31.69	<0.01	3-1	3.15	<0.01			
				3-2	1.71	<0.01			
				2-1	1.38	0.017			
Virginia rail	TYPE	19.43	0.01	3-1	2.38	<0.01			
				3-2	1.53	0.01			
Pie-billed grebe	TYPE	6.50	0.022	3-1	-1.67	<0.01			
				2-1	-0.91	0.029			
Canada goose	TYPE	17.48	<0.01	3-2	-4.14	<0.01			
				2-1	3.82	<0.01			
Wood duck	TYPE	13.06	<0.01	3-1	3.78	<0.01			
				3-2	3.21	0.01			
Mallard	TYPE	4.99	0.045	*2-1*	*1.83*	*0.057*	2-1	2.14	0.027
	COMPLEX	7.54	0.018						
Spotted sandpiper	n.s.	n.s.							
VISITORS									
Great blue heron	TYPE	9.56	0.01	3-1	-0.75	0.023	3-1	0.85	0.011
	COMPLEX	10.46	<0.01	3-2	-0.74	0.021	3-2	0.83	0.023
American Coot	TYPE	6.95	0.013	3-1	-1.72	0.014	3-1	1.57	0.025
	COMPLEX	7.02	0.021						
Great egret	COMPLEX	6.91	0.022				3-1	1.01	0.040
							3-2	1.07	0.033
Yellow warbler	TYPE	24.24	<0.01	3-1	2.24	<0.01			
				3-2	1.47	<0.01			
Green heron	TYPE	2.88	0.019	2-1	0.87	0.041			
Belted kingfisher	n.s.								
Eastern kingbird	n.s.								
Tree swallow	n.s.								
N.-rough-winged sw.	n.s.								
Blue-winged teal	n.s.								
Kildeer	n.s.								
Migrating shorebirds	TYPE	8.45	0.014	3-2	-9.93	0.029			
				2-1	8.99	0.036			
Migrating waterfowl	TYPE	6.08	0.029	3-2	-17.17	0.031	3-1	17.64	0.041
	COMPLEX	5.41	0.038						

Table 4. Species richness observed in replacement wetlands in Ohio 2001-2002.

		Test of between-subject effects		Pairwise comparisons among the levels of main between-subject effects					
				TYPE			COMPLEX		
		$F_{(2.17)}$	P	Comp.	Mean diff.	P	Comp.	Mean diff.	P
Breeding birds	TYPE	15.79	<0.01	3-1	5.16	<0.01			
				2-1	2.69	0.040			
				3-2*	2.47	0.073			
Visitors	TYPE	11.45	0.01	3-1	5.66	0.010	3-1	4.71	0.021
	COMPLEX	7.21	0.020	2-1	3.69	0.034			
All species [(a)]	TYPE	13.68	<0.01	3-1	10.82	<0.01			
				2-1	6.38	0.033			
Migrating waterfowl	COMPLEX	46.47	<0.01	3-1	3.48	<0.01			
				3-2	3.75	<0.01			
Migrating shorebirds	TYPE	5.16	0.042						

[(a)] Not including migrating waterfowl and shorebirds

Migrant waterfowl and shorebirds

Total counts of migrating waterfowl were highest in low vegetation wetlands, and significantly higher in wetlands within larger wetland complexes (Complex 3) than in isolated wetlands or wetlands located within smaller complexes. Observed densities of migrating shorebirds were significantly higher in low vegetation wetlands than in high vegetation wetlands and perimeter wetlands (Table 3).

Discussion

My results indicate that wetland birds differ in their habitat requirements, and that creation of different wetland types is necessary to maintain bird diversity. As expected, one-type-does-not-fit-all, and careful consideration needs to be given to designing replacement wetlands in order to provide habitat for all of our region's wetland-dependent birds.

Vegetation cover

High vegetation cover wetlands (>60% vegetation cover, Type 3) had the highest breeding bird, "visitors", and overall species richness. With the exception of Canada geese and mallards, all breeding species attained significantly higher densities than in other two types of replacement wetlands.

Low vegetation cover wetlands (~ 30% emergent vegetation cover, Type 2) have significantly higher breeding bird species richness and birds in the "non-breeder" category than perimeter wetlands (Type 1). Canada geese, mallards, and green herons attain highest densities at these sites, and densities of red-winged blackbirds, American coots, and belted kingfishers are not significantly different from densities observed at high vegetation cover wetlands (Type 3). Observed densities of migrating shorebirds and waterfowl were greatest at this type of wetlands, as well.

Wetlands with less than 10% vegetation cover (Type 1) have the lowest breeding bird species richness. Of all the wetland-dependent breeding bird species in our region, only the pie-billed grebe achieves the highest density in this type of wetlands. This type of wetland also has the lowest bird species richness in the"non-breeder" category. Only the great blue heron and the American coot are significantly more common in this type of wetland habitat than in other wetland types. Density of migrating shorebirds is significantly lower in these types of wetlands compared to low vegetation cover wetlands, and densities of migrating waterfowl are not significantly different from other types of wetland designs. In summary, these wetlands provide adequate habitat for only a small subset of wetland bird species in our region. However, these wetlands are a very common type of replacement wetlands constructed in Ohio and other states. Absence of a shallow, vegetated littoral zone, which provides suitable egg laying, foraging and refugia sites for pond-breeding amphibians, limits the amphibian use of these sites as well. These wetlands resemble gamefish ponds in design (Illinois Department of Conservation 1995), and are of little value in amphibian conservation (Lanoo 1996). Porej (2003b) surveyed the amphibian communities during the same time period, and found that these wetlands have depauperate amphibian communities dominated by ranid frogs (bullfrogs, green frogs and leopard frogs), with few records of spring peepers, gray treefrogs and American toads, and no records of any pond-breeding salamanders.

Wetland size and complex size

Species richness and densities of several species and groups of species, including migrating waterfowl, were associated with the size of the wetland complex within which the study site was created.

This result suggests that creation of larger wetland complexes should be preferred over the creation of isolated wetlands. My results agree with the results of other studies on wetland-dependent organisms including birds (Delnicki and Rienecke 1986, Fredrikson and Reid 1986, Firbairn and Dinsmore 2001), aquatic snakes (Russel and Hanlin 1999, Roe and Kingsbury, unpublished) and turtles (Joyal et al. 2001). These studies demonstrate that a single wetland often cannot provide all the necessary resources, and that it is important to have different wetland types in close juxtaposition to provide adequate foraging, nesting and over wintering sites.

Due to the specific issues facing wetland mitigation, it is very important to differentiate between the issue of whether to encourage the creation of wetland complexes vs. individual wetlands, and a separate issue of creation of one large wetland vs. a complex of smaller wetlands of the same cumulative size. The distinction is far from trivial, but some authors fail to differentiate between the two (e.g., Rogers 1996).

The size of the *individual wetland* basin may indeed be important for certain area-sensitive bird species and groups in marshes under 6ha in size (Nudds 1992, Vanrees-Siewart and Dinsmore 1996). Brown and Dinsmore (1986) demonstrate that there is a significant increase in species richness with increasing wetland area for Iowa marshes <5.5ha, but that the species-area curve slope becomes not significantly different form zero for larger marshes (8.3-182ha). Of 18 breeding species in Iowa that Brown and Dinsmore (1986) classified as area-dependent or possibly area-dependent, 10 breed in inland marshes of central Ohio. Eight of those species were breeding in at least one of my study sites (all under 4.12ha), and the other two (ruddy duck and American bittern, both very rare breeders in central Ohio) were recorded, but not breeding at my study sites. Another species that is possibly area-dependent, but now a very rare breeder in central Ohio is the common moorhen (*Gallinula chloropus*; Chabot 1996). Therefore, while the size of the *wetland complex* is positively associated with densities of some bird species and groups, my data suggests that the *individual wetlands* of 4ha can provide adequate habitat for all wetland birds breeding in inland marshes in Ohio (with possible exception of the three above-mentioned species), as long as suitable vegetation is present. Similarly, the composition of pond-breeding amphibian communities is not dependent on the size of the individual wetland area, but rather on other factors such as the duration of hydroperiod, presence of predatory fish, presence of shallow littoral zones, and the composition of the surrounding landscape (Penchmann et al. 1989, Semlitsch and Bodie 1998, Semlitsch 2000, Snodgrass et al. 2000, Weyrauch and Grubb 2004, Porej (2003b), which are independent of wetland size.

This distinction has important implications for how we create replacement wetlands. Wetland mitigation projects in Ohio commonly entail replacement of several impacted wetlands by a single, large wetland (Porej, unpublished). Conversion of many smaller wetlands into much fewer larger ones is particularly apparent in the construction and design of wetland mitigation banks. I posit that this is done for a variety of practical reasons (a need to predict water levels relative to property lines), economic (e.g., maximizing the amount of wetland acreage on limited amount of property available, construction and maintenance of one dike vs. many), legal (easier compliance with the ACOE criteria for a successful wetland replacement), and other management reasons (the “misconception of stable water”; Frederickson and Reid 1990:79).

In addition to these non-diversity related reasons for constructing a single, large site, is would be reasonable to expect that larger sites would be more likely to develop several vegetation zones, therefore achieving high diversity. My survey of all replacement emergent marshes constructed under£401 in Ohio within the last 15 years suggests that this is not the case. Over 36% of all wetlands created in Ohio under£401 are perimeter wetlands, and over 75% of those sites are more than 6 years old. Creation of wetland replacement sites with steep bank slopes, compacted soils, and permanent standing water limits the rate of habitat development at these types of projects.

Rather than creating one large wetland, creation of several diverse wetlands within a complex should be encouraged in order to improve our chances to recreate adequate habitat for all wetland bird species in our region.

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